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The petrology, mineralogy and geochemistry of the large Fen Carbonatite Complex (Norway) REE-Nb resource

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The c.580 Ma Fen Carbonatite Complex in Southern Norway is a circular, c.2.5 km diameter pipe-like composite intrusion (Figure 1) consisting of highly alkaline rocks (ijolite), carbonatites and ultramafic lamprophyres (damtjernites). The Fen Complex is also the type area for the pervasive Na–K metasomatic alteration of country-rock gneisses referred to as ‘fenitisation’ and it is the location where the magmatic origin of carbonatites was first proposed by Brøgger in 1920s. The Fen Complex is almost certainly the largest REE resource on the European continent with a resource size estimate of >100 MT at c.1 wt-% REE-oxide. We will present results from our on-going research project which looks at the key geological stages in the formation of this REE resource, from mantle metasomatism and melting, to late/post-magmatic alteration.

Our research has shown that primary magmatic carbonatite in the Fen Complex is calcite-dolomite carbonatite with relatively low grades of REE (typically <2000 ppm Σ -REE), hosted in REE-fluorocarbonate and fluorapatite. These rocks locally contain abundant metasomatic pyrochlore and columbite (up to 5000 ppm Nb) in magnetite-rich zones. In many areas, especially in the eastern part of the intrusion, the primary calcite-dolomite carbonatite is transformed into a red, secondary hematite-carbonatite known locally as Rødbergite. In Rødbergite, REE are greatly enriched (4000–15000 ppm Σ -REE). The transformation of calcite-dolomite carbonatite to Rødbergite is associated with the breakdown of REE-fluorocarbonate and fluorapatite to form secondary REE-monazite.

There is geochemical evidence that LREE and HREE are partly decoupled during the transformation, and transitional, partly transformed carbonatite contains relatively low HREE/LREE ratios. Apatite aggregates (probably originally of a cumulate origin) acted as a trap for oxidising REE-bearing fluids. Sr and Nd isotope analysis shows that while primary carbonatites have mantle signatures (relatively depleted with respect to CHUR at 580 Ma, $\epsilon_{\text{Nd}}(580 \text{ Ma}) +4$), the transformation to Rødbergite is associated with a strong relative increase in radiogenic ^{87}Sr , clearly pointing to a key role for ‘external’ fluids with a crustal isotopic signature in the formation of secondary Rødbergite. We will outline models for the nature of the Rødbergite formation processes, and discuss the possible geological context for this event.

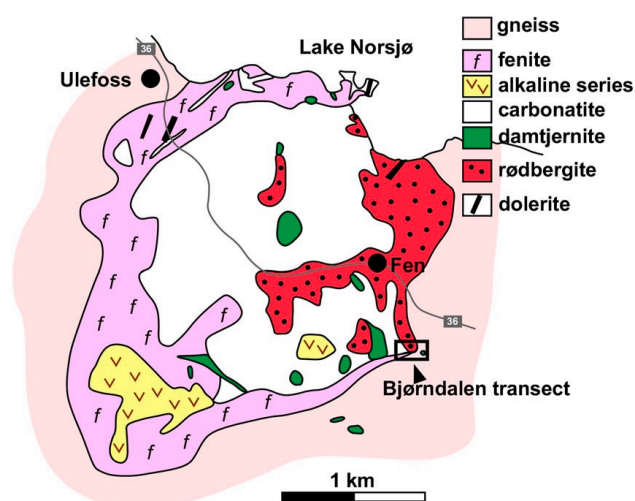


Figure 1. Simplified map of the Fen Complex, based on NGU map (geo.ngu.org) and our own data. Our key sampling transect is marked in box. Rødbergites, i.e. strongly REE-enriched secondary hematites are highlighted.